CLAIMS

What is claimed is:

1. An optical apparatus, comprising an optical element having formed therein at least one set of diffractive elements and at least two channel optical waveguides, each channel optical waveguide having a corresponding first end and substantially confining in two transverse spatial dimensions an optical signal propagating therein, wherein:

diffractive elements of each set of diffractive elements are distributed among diffractive element subsets corresponding to each of at least two of the channel waveguides;

each diffractive element set routes, between a corresponding pair of optical ports, those corresponding portions of an optical signal propagating within the optical element that are received by at least two of the channel waveguides and back-diffracted within the receiving channel waveguides by corresponding diffractive element subsets;

the channel optical waveguides are arranged so that an optical signal entering the optical element at an input optical port first propagates through a region of the optical element between the input optical port and the first ends of the channel waveguides and is then incident on and received at least in part by the corresponding first ends of at least two of the channel optical waveguides; and

the channel optical waveguides are arranged so that the corresponding routed portions of optical signal exiting the optical element at an output optical port first propagate through a region of the optical element between the first ends of the channel waveguides and the output optical port.

2. The optical apparatus of Claim 1, wherein regions of the optical element between optical ports and the first ends of the channel waveguides comprise at least one slab optical waveguide, the slab waveguide substantially confining in one transverse spatial dimension an optical signal propagating in two dimensions therein.

3. The optical apparatus of Claim 2, wherein the slab waveguide comprises a core layer surrounded by lower-index cladding layers.

4. The optical apparatus of Claim 2, wherein the slab waveguide and the channel waveguides are formed on a common substrate.

5. The optical apparatus of Claim 1, wherein an optical signals propagate in three dimensions in regions of the optical element between optical ports and the first ends of the channel waveguides.

6. The apparatus of Claim 1, wherein relative spatial arrangement of the first ends of the channel waveguides and corresponding relative phase shifts imparted on back-diffracted portions of the optical signal in the channel waveguides define at least in part a relative spatial arrangement of the corresponding pair of optical ports.

7. The apparatus of Claim 6, wherein the corresponding longitudinal positions of the diffractive element subsets along the corresponding channel waveguides at least partly determine the corresponding imparted phase shifts.

8. The apparatus of Claim 6, wherein at least one channel waveguide includes a corresponding static phase-shifting element that at least partly determines the corresponding imparted phase shifts.

9. The apparatus of Claim 6, wherein at least one channel waveguide includes a phase modulator that at least partly determines the corresponding imparted phase shifts.

10. The apparatus of Claim 9, wherein the relative spatial arrangement of the corresponding optical ports shifts in response to a control signal applied to the phase modulator.

11. The apparatus of Claim 6, wherein:

at least two of the channel optical waveguides include corresponding broadband reflectors that provide substantial reflectivity over an operating wavelength range of the optical apparatus;

the broadband reflectors route, between another corresponding pair of optical ports, those corresponding portions of an optical signal propagating within the optical element that are received by at least two of the channel waveguides, substantially transmitted by the diffractive element set, and redirected within the receiving channel waveguides by the corresponding broadband reflectors; and

wherein relative spatial arrangement of the first ends of the channel waveguides and corresponding relative phase shifts imparted on redirected portions of the optical signal in the channel waveguides define at least in part a relative spatial arrangement of the other corresponding pair of optical ports.

12. The apparatus of Claim 11, wherein the corresponding longitudinal positions of the broadband reflectors along the corresponding channel waveguides at least partly determine the corresponding phase shifts imparted on redirected portions of the optical signal.

13. The apparatus of Claim 11, wherein at least one channel waveguide includes a corresponding static phase-shifting element that at least partly determines the corresponding phase shifts imparted on redirected portions of the optical signal.

14. The apparatus of Claim 11, wherein at least one channel waveguide includes a phase modulator that at least partly determines the corresponding phase shifts imparted on redirected portions of the optical signal.

15. The apparatus of Claim 14, wherein the relative spatial arrangement of the other corresponding pair of optical ports shifts in response to a control signal applied to the phase modulator.

16. The apparatus of Claim 11, wherein the first pair of optical ports comprises an input port and a dropped-channel port, the other pair of optical ports comprises the

input port and an output port, and the apparatus functions as a channel-dropping demultiplexer.

17. The apparatus of Claim 11, wherein the first pair of optical ports comprises an added-channel port and an output port, the other pair of optical ports comprises an input port and the output port, and the apparatus functions as a channel-adding multiplexer.

18. The apparatus of Claim 6, wherein:

at least two of the channel waveguides route, between another corresponding pair of optical ports, those corresponding portions of an optical signal propagating within the optical element that are received by at least two of the channel waveguides, substantially transmitted by the diffractive element set, and emitted from corresponding second ends of the routing channel waveguides; and

wherein relative spatial arrangement of the first ends of the channel waveguides, relative spatial arrangement of the second ends of the channel waveguides, and corresponding relative phase shifts imparted on transmitted portions of the optical signal by the channel waveguides define at least in part a relative spatial arrangement of the other corresponding pair of optical ports.

19. The apparatus of Claim 18, wherein corresponding lengths of the corresponding channel waveguides at least partly determine the corresponding phase shifts imparted on transmitted portions of the optical signal.

20. The apparatus of Claim 18, wherein at least one channel waveguide includes a corresponding static phase-shifting element that at least partly determines the corresponding phase shifts imparted on transmitted portions of the optical signal.

21. The apparatus of Claim 18, wherein at least one channel waveguide includes a phase modulator that at least partly determines the corresponding phase shifts imparted on transmitted portions of the optical signal.

22. The apparatus of Claim 21, wherein the relative spatial arrangement of the other corresponding pair of optical ports shifts in response to a control signal applied to the phase modulator.

23. The apparatus of Claim 18, wherein the first pair of optical ports comprises an input port and a dropped-channel port, the other pair of optical ports comprises the input port and an output port, and the apparatus functions as a channel-dropping demultiplexer.

24. The apparatus of Claim 18, wherein the first pair of optical ports comprises an added-channel port and an output port, the other pair of optical ports comprises an input port and the output port, and the apparatus functions as a channel-adding multiplexer.

25. The apparatus of Claim 18, wherein the corresponding second ends of the channel waveguides are structurally adapted for optical coupling with one optical port of the other corresponding pair of optical ports.

26. The apparatus of Claim 6, wherein the corresponding first ends of the channel waveguides are structurally adapted for optical coupling with the corresponding pair of optical ports.

27. The apparatus of Claim 26, wherein the corresponding first ends of the channel waveguides are flared.

28. The apparatus of Claim 26, wherein the corresponding first ends of the channel waveguides are tapered.

29. The apparatus of Claim 26, wherein the corresponding first ends of the channel waveguides have segmented cores.

30. The apparatus of Claim 26, wherein end faces of the corresponding first ends of the channel waveguides are curved.

31. The apparatus of Claim 1, wherein the diffractive element set imparts at least one of spectral characteristics and temporal characteristics onto the corresponding back-diffracted portions of the optical signal, thereby determining at least in part at least one of spectral characteristics and temporal characteristics of the routed portion of the optical signal.

32. The apparatus of Claim 31, wherein the diffractive element subsets impart substantially the same characteristics onto the corresponding back-diffracted portions of the optical signal.

33. The apparatus of Claim 31, wherein the diffractive element subsets impart differing characteristics onto the corresponding back-diffracted portions of the optical signal.

34. The apparatus of Claim 31, wherein corresponding resonance wavelengths for the corresponding back-diffracted portions of the optical signal are determined at least in part by longitudinal spacing of the diffractive elements of the corresponding subsets.

35. The apparatus of Claim 34, wherein the longitudinal spacing is substantially constant over the diffractive element set.

36. The apparatus of Claim 34, wherein the longitudinal spacing is substantially constant within each of the diffractive element subsets.

37. The apparatus of Claim 34, wherein the longitudinal spacing varies over the diffractive element set.

38. The apparatus of Claim 34, wherein the longitudinal spacing varies within each diffractive element subset.

39. The apparatus of Claim 31, wherein at least one of amplitude and phase of sub-portions, diffracted by single diffractive elements, of the corresponding back-diffracted portions of the optical signal is controlled by at least one of relative

positioning of the individual diffractive elements and configuration of the individual diffractive elements.

40. The apparatus of Claim 31, wherein the diffractive element set imparts spectral characteristics onto the back-diffracted portions of the optical signal, the optical apparatus thereby functioning as a spectral filter.

41. The apparatus of Claim 40, wherein the optical apparatus functions as a multiplexer/demultiplexer.

42. The apparatus of Claim 41, wherein:

the corresponding pair of optical ports comprise a multiplexing optical port and at least one of an input optical port and an output optical port;

wherein relative spatial arrangement of the first ends of the channel waveguides and corresponding relative phase shifts imparted on back-diffracted portions of the optical signal in the channel waveguides define at least in part a relative spatial arrangement of the multiplexing optical port and at least one of the input optical port and the output optical port;

at least two of the channel optical waveguides include corresponding broadband reflectors that provide substantial reflectivity over an operating wavelength range of the optical apparatus;

the broadband reflectors route, between the input optical port and the output optical port, those corresponding portions of an optical signal propagating within the optical element that are received by at least two of the channel waveguides, substantially transmitted by the diffractive element set, and redirected within the receiving channel waveguides by the corresponding broadband reflectors; and

relative spatial arrangement of the first ends of the channel waveguides and corresponding relative phase shifts imparted on redirected portions of the optical signal in the channel waveguides define at least in part a relative spatial arrangement of the input optical port and the output optical port.

43. The apparatus of Claim 41, wherein:

the corresponding pair of optical ports comprise a multiplexing optical port and at least one of an input optical port and an output optical port;

wherein relative spatial arrangement of the first ends of the channel waveguides and corresponding relative phase shifts imparted on back-diffracted portions of the optical signal in the channel waveguides define at least in part a relative spatial arrangement of the multiplexing optical port and at least one of the input optical port and the output optical port;

at least two of the channel waveguides route, between the input optical port and the output optical port, those corresponding portions of an optical signal propagating within the optical element that are received by at least two of the channel waveguides, substantially transmitted by the diffractive element set, and emitted from corresponding second ends of the routing channel waveguides; and

relative spatial arrangement of the first ends of the channel waveguides, relative spatial arrangement of the second ends of the channel waveguides, and corresponding relative phase shifts imparted on transmitted portions of the optical signal in the channel waveguides define at least in part a relative spatial arrangement of the input optical port and the output optical port.

44. The apparatus of Claim 31, wherein the diffractive element set imparts temporal characteristics onto the corresponding back-diffracted portions of the optical signal, the optical apparatus thereby functioning as a temporal encoder.

45. The apparatus of Claim 1, further comprising multiple diffractive element sets, diffractive elements of each set of diffractive elements being distributed among diffractive element subsets corresponding to each of at least two of the channel waveguides, each diffractive element set imparting at least one of spectral characteristics and temporal characteristics onto the corresponding back-diffracted portions of the optical signal, thereby determining at least in part at least one of spectral characteristics and temporal characteristics of the corresponding routed portions of the optical signal.

46. The apparatus of Claim 45, wherein at least two sets of diffractive elements impart distinct characteristics onto their respective back-diffracted portions of the optical signal.

47. The apparatus of Claim 45, wherein at least two of the multiple diffractive element sets are overlaid.

48. The apparatus of Claim 45, wherein at least two of the multiple diffractive element sets are stacked.

49. The apparatus of Claim 45, wherein at least two of the multiple diffractive element sets are interleaved within at least one common channel waveguide.

50. The apparatus of Claim 45, wherein at least two of the multiple diffractive element sets are interleaved among multiple of the channel waveguides.

51. The apparatus of Claim 50, wherein each channel waveguide has at most one subset of diffractive elements.

52. The apparatus of Claim 1, wherein routing of the back-diffracted portions of the optical signal exhibits a designed dependence on polarization of the optical signal.

53. The apparatus of Claim 52, wherein routing of the back-diffracted portions of the optical signal is substantially independent of the polarization of the optical signal.

54. The apparatus of Claim 1, wherein routing of the back-diffracted portions of the optical signal exhibits a designed dependence on temperature of the optical element over an operating temperature range.

55. The apparatus of Claim 54, wherein routing of the back-diffracted portions of the optical signal is substantially independent of the temperature of the optical element over an operating temperature range.

56. The apparatus of Claim 1, wherein routing of the back-diffracted portions of the optical signal includes conjugate-ratio imaging of one of the corresponding pair of optical ports onto the other of the corresponding pair of optical ports.

57. The apparatus of Claim 1, wherein routing of the back-diffracted portions of the optical signal includes propagation between the ends of the channel waveguides and at least one of the corresponding pair of optical ports as an optical mode substantially collimated in an unconfined transverse dimension.

58. The apparatus of Claim 1, further comprising a second similar optical element having formed therein at least one set o diffractive elements and at least two channel optical waveguides, wherein an output optical port of the first optical element serves as an input optical source for an input optical port of the second optical element.